BENCH-SCALE PROCESS FOR LOW-COST CARBON DIOXIDE (CO_2) CAPTURE USING A PHASE-CHANGING ABSORBENT

DE-FE0013687

GE Global Research

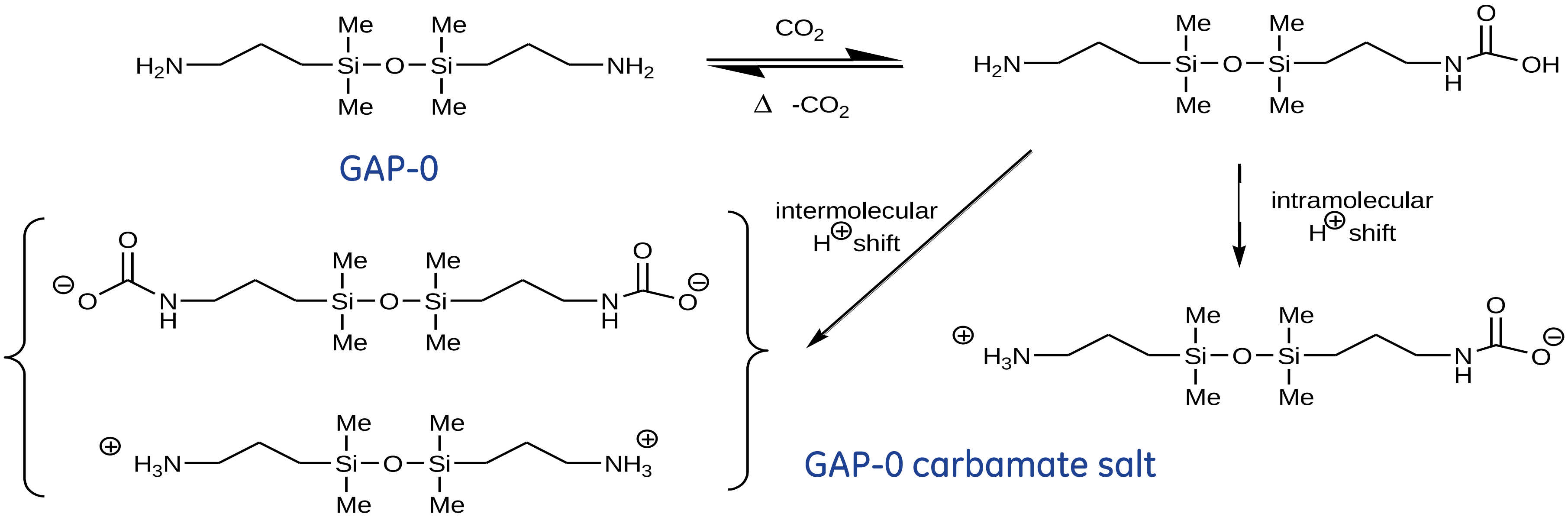
Tiffany Westendorf

Budget Period 1 Briefing
February 23, 2015

Agenda

- Technical Background
- Project Structure
- Progress Report by Task
- Budget Period 1 Status
- Plans for Budget Period 2
- Q&A

Chemistry of GAP-0 reaction with CO_2



- Extensive screening of multiple solvents
- Absorbs CO_2 very rapidly in the 40-50°C range
- High CO_2 loading (>17% weight gain, >95% of theoretical value)
- Carbamate readily decarboxylates at higher temps
- Carbamate is solid → new process configuration

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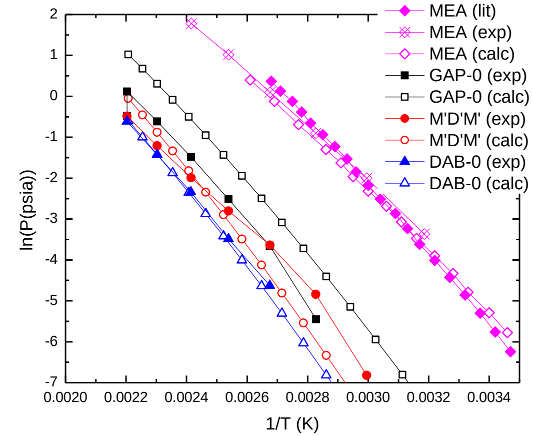
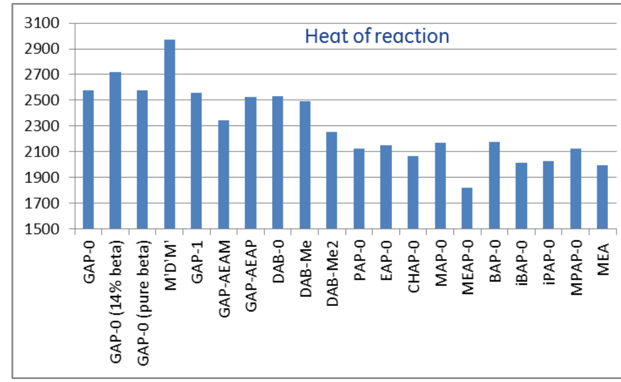
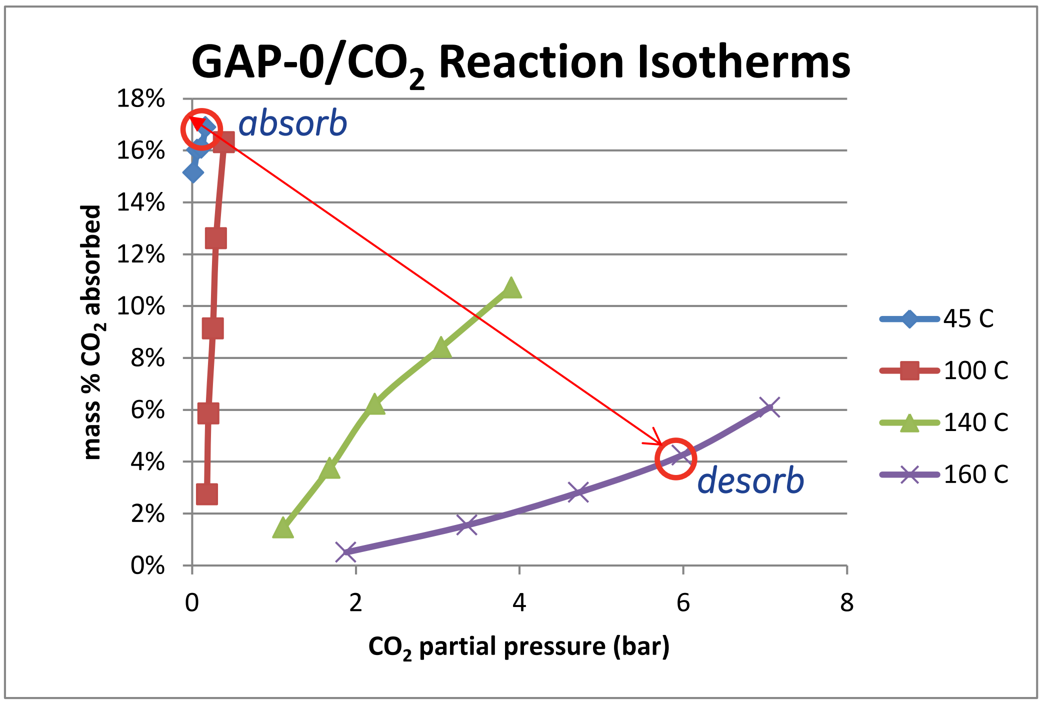
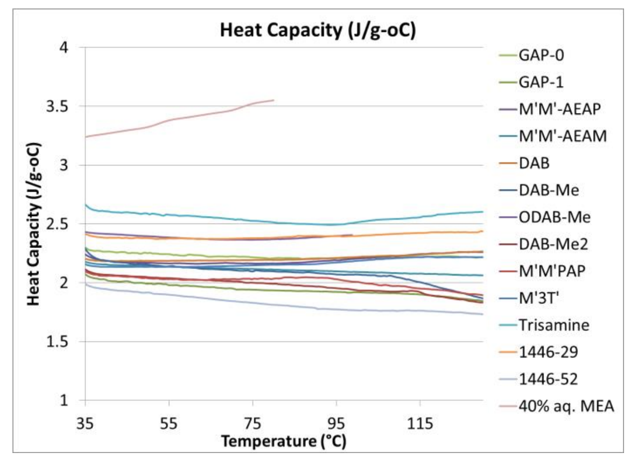
GAP-0 Properties

- Lower vapor pressure vs. MEA
- Higher heat of reaction vs. MEA
- Lower heat capacity vs. MEA
- >11% Dynamic CO_2 capacity @ 6 bara









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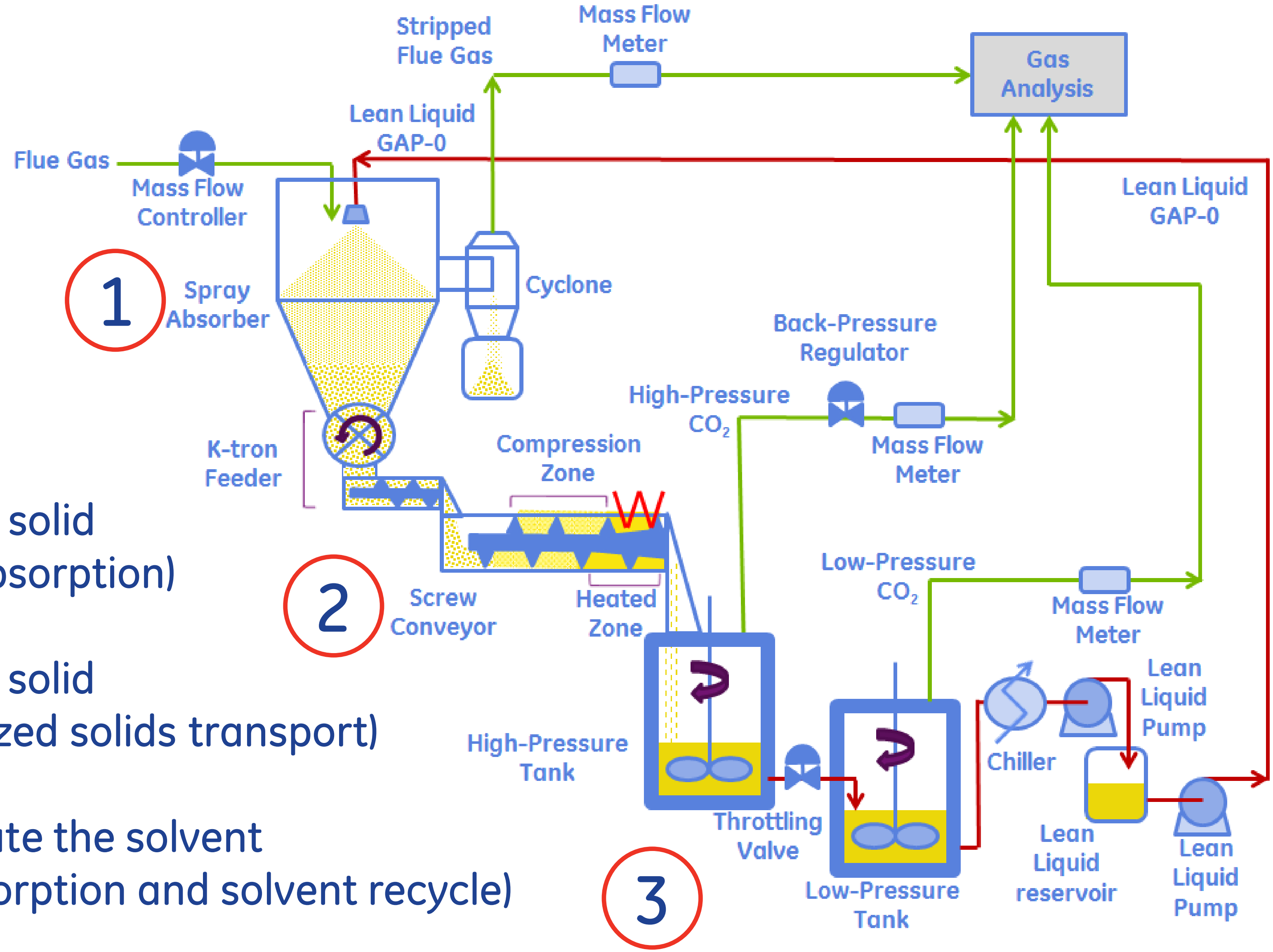
Phase-Changing CO_2 Capture System



1 Make the solid
(Spray absorption)

2 Move the solid
(Pressurized solids transport)

3 Regenerate the solvent
(CO_2 desorption and solvent recycle)

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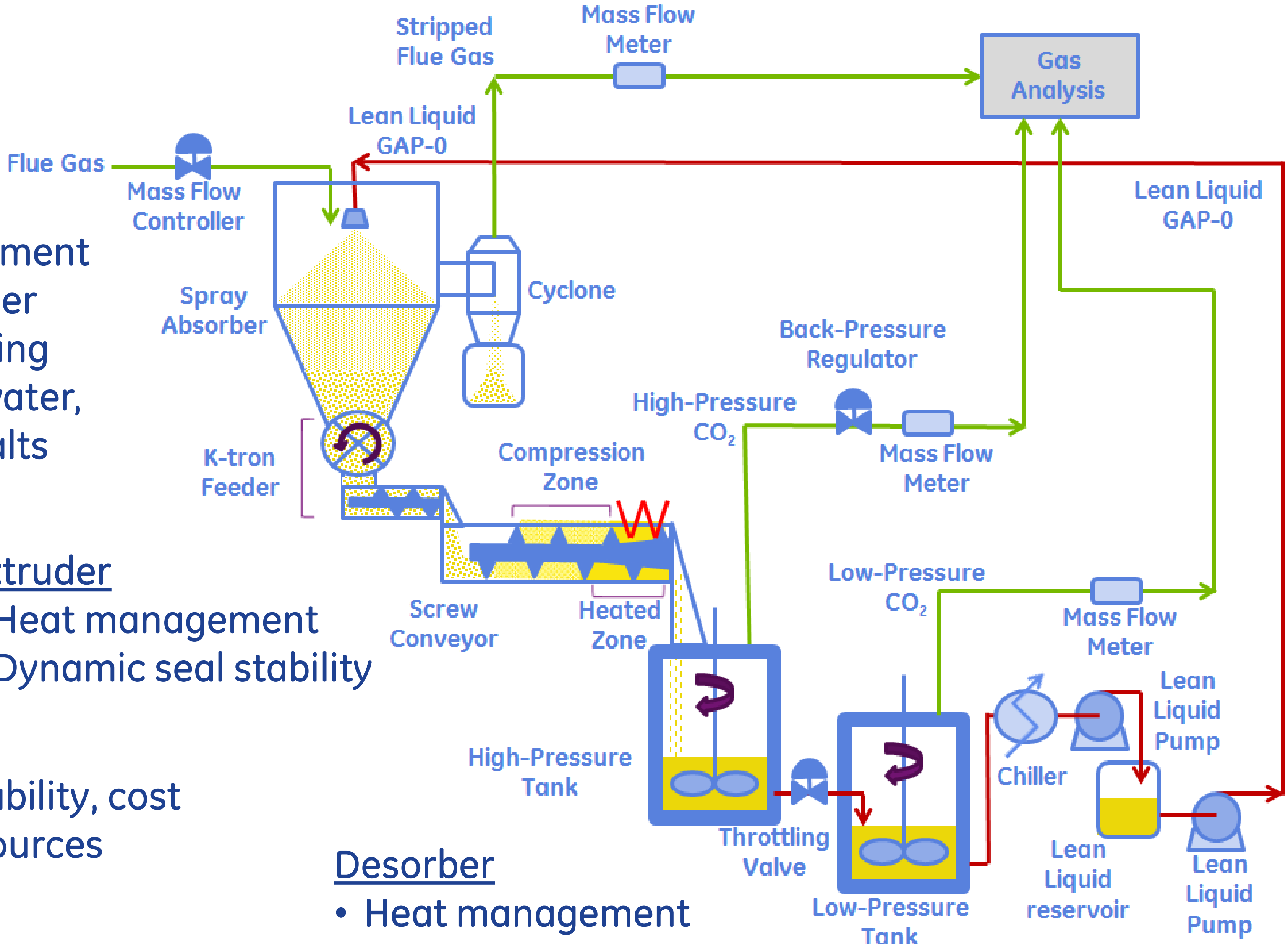
Risk Assessment



Absorber

- Heat management
- GAP-0 β-isomer
- Atomizer fouling
- Presence of water, heat stable salts

Extruder

- Heat management
- Dynamic seal stability

Project

- Solvent availability, cost
- Expertise resources

Desorber

- Heat management
- Corrosion

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BENCH-SCALE PROCESS FOR CO_2 CAPTURE USING A PHASE-CHANGING ABSORBENT

Program Team

GE Global Research Niskayuna

- Bench-Scale Design
- Construction/operation of Continuous System
- EH & S Assessment
- Techno-Economic Assessment

coperion
confidence through partnership

- Extruder Design
- Component Integration
- Heat Management

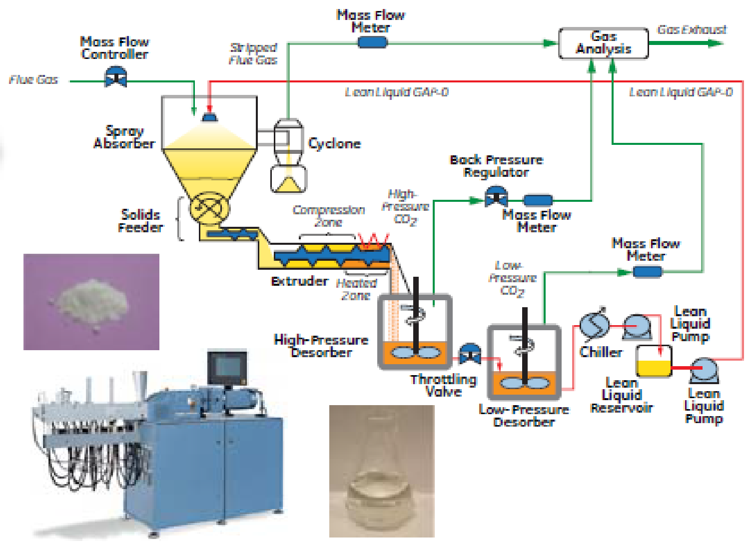
Gelest
SILAR LABORATORIES
SiVance

Solvent Manufacturers

- Aminosilicone Supply

36 Month, \$3.0MM Program to Develop a Phase-Change Process for CO_2 Capture

Program Objective: *Design and optimize a new process for a novel silicone CO_2 capture solvent and establish scalability and potential for commercialization of post-combustion capture of CO_2 from coal-fired power plants. A primary outcome will be a system capable of 90% capture efficiency with less than \$40/tonne CO_2 capture cost.*



Technical Approach

- Design and construct bench-scale unit and obtain parametric data to determine key scale-up parameters
- Perform an EH & S and technical and economic assessment to determine feasibility of commercial scale operation
- Develop scale-up strategy

\$2.4M DOE share
1/1/2014 – 12/31/2016

Program Deliverables

- Strategy for future scale-up
- Technical and economic feasibility determined
- Environmental assessment

Anticipated Benefits of the Proposed Technology

- 90% CO_2 capture
- \$40/tonne CO_2 capture cost

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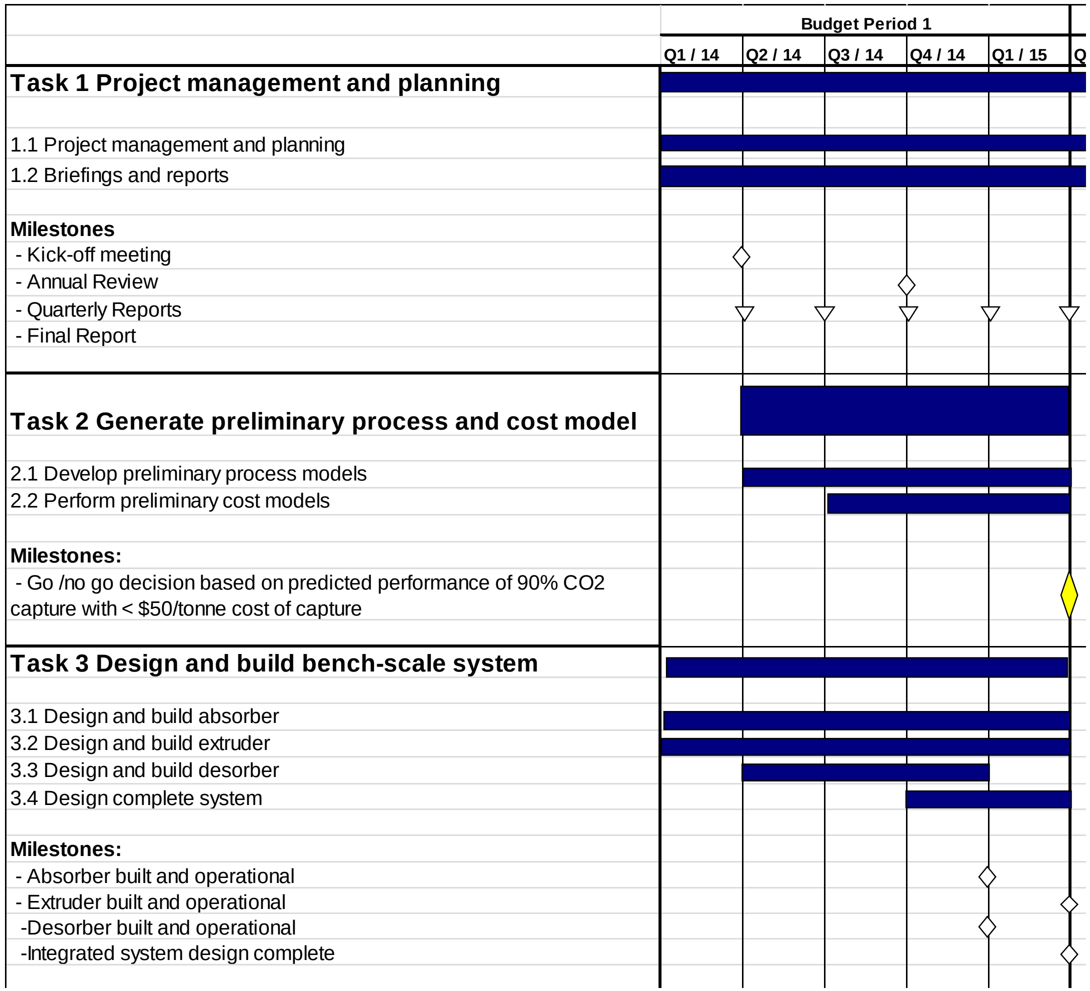
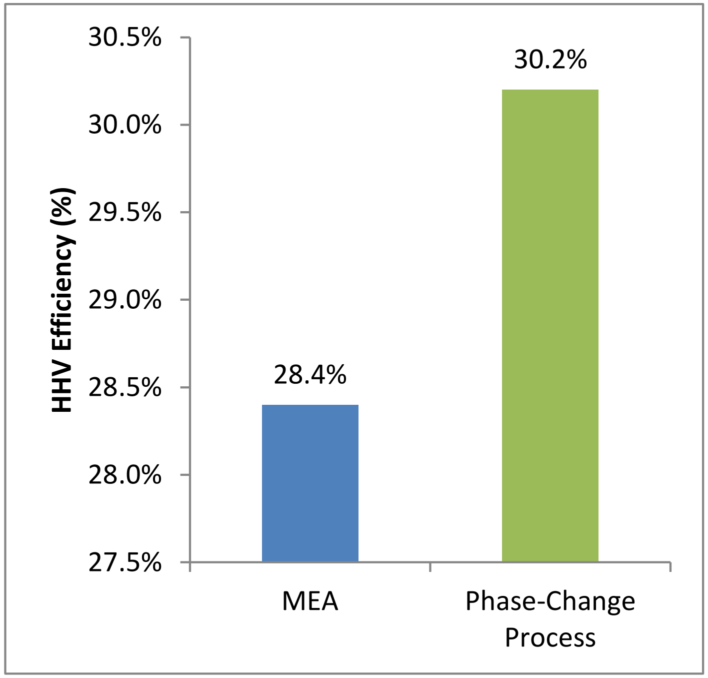
Project Structure

- Budget Period 1: Design and Build [2014]
  - Spray absorber, extruder, desorber
  - Preliminary Technical and Economic Assessment
  - Go/No-go: 90% CO_2 Capture, <$50/tonne CO_2
- Budget Period 2: Unit Operations Testing [2015]
  - Optimize individual unit operations separately
  - Solvent manufacturability study and EH&S risk assessment
  - Update Technical and Economic Assessment
  - Go/No-go: 90% CO_2 Capture, <$45/tonne CO_2
- Budget Period 3: Continuous System Operation [2016]
  - Integrate unit ops into continuous system, generate engineering data for scaleup
  - Final Technical and Economic Assessment
  - Goal: 90% CO_2 Capture, <$40/tonne CO_2

Project Schedule: BP1



Task 2: Preliminary Process and Cost Modeling



- Model reflects Case 12 of Bituminous Baseline Study, scaled to 550MW net power output
- Incorporated custom property basis for GAP-0
- CO_2 capture system integrated with power plant
- High efficiency driven by high dynamic CO_2 loading, heat integration

Phase-changing aminosilicone process offers substantially higher efficiency, lower cost vs. MEA

Task 3: Design and Build – Absorber

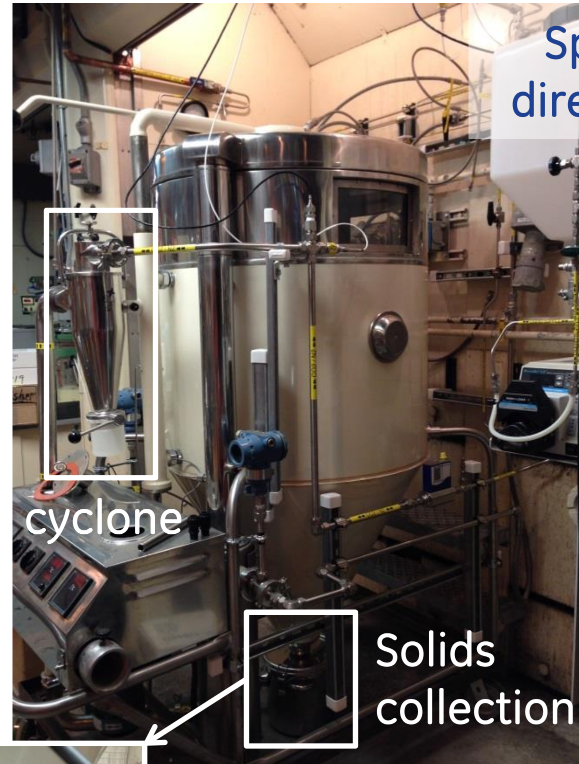
Features

- efficient spray formation
    - Choice of atomizers
- disengagement of particles from gas
    - Co-current, downward spray flow
    - Cyclone solids collection
- wide range of liquid and gas flow rates
    - up to 200mL/min solvent flow rate
    - up to 500slm gas flow rate
- wide range of gas composition
    - 0-100% CO_2 in N_2
    - SO_2, NO capability
    - Humidity

	Hydraulic Nozzle	Two-Fluid Nozzle	Rotary Atomizer
Atomization mode	Liquid pressure, internal geometry	Gas pressure	Spinning disk
Cost at bench scale	+	+	-
Droplet size	-	+	+
Droplet size during startup	-	+	+
Atomization independent of CO_2:GAP-0 feed ratio	+	-	+
Compatible with bench-scale liquid flowrate	+	+	+

Task 3: Design and Build – Absorber

Gas supply system

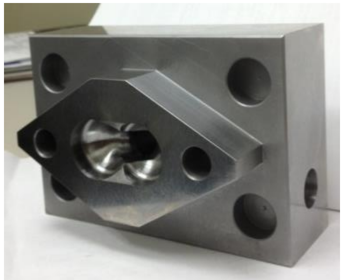


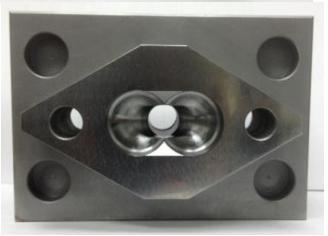
Spray absorber and liquid supply system

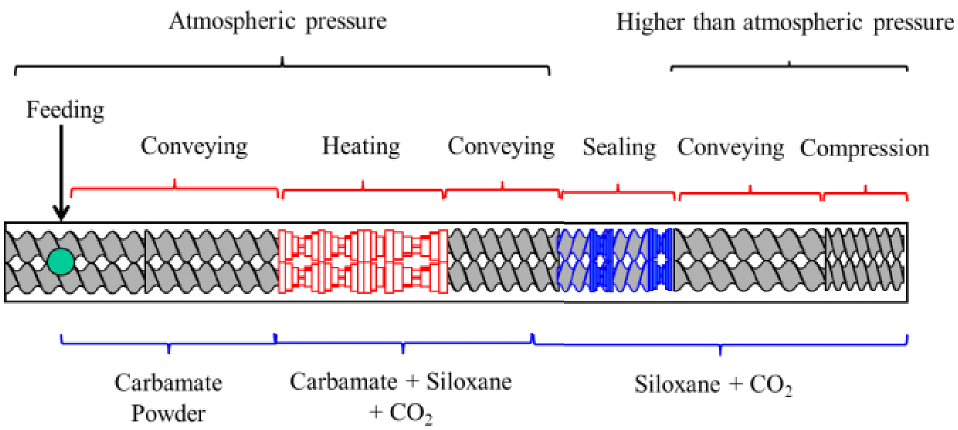
Task 3: Design and Build – Extruder

Features

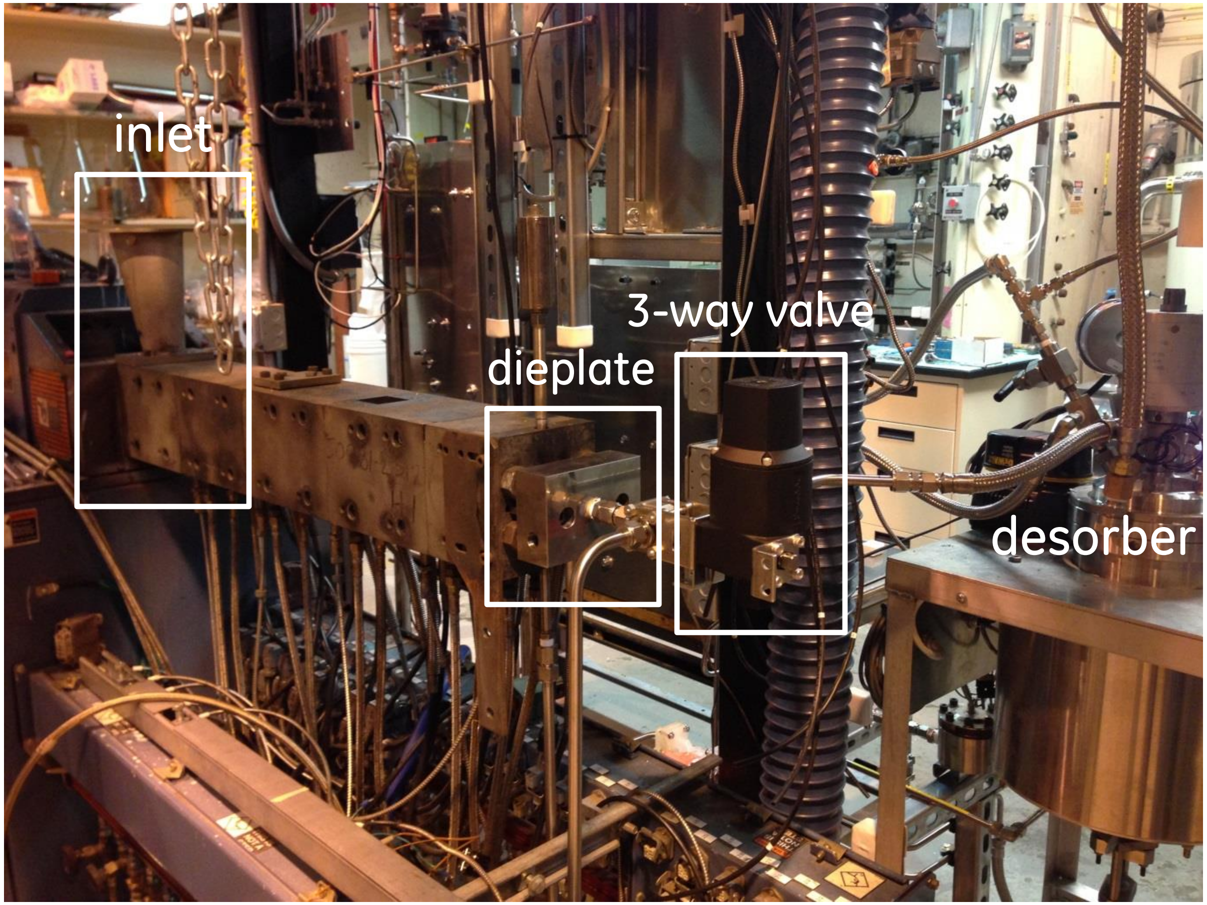
- feed 5-30 lb/hr solids
  - 25mm screw diameter
  - K-Tron loss-in-weight feeder
- maintain dynamic seal against pressure
  - Modular screw elements → optimized screw
  - Optimized barrel heating profile
- connection to desorber
  - custom dieplate
  - melt temperature
  - pressure relief
  - desorber bypass for startup







Task 3: Design and Build – Extruder

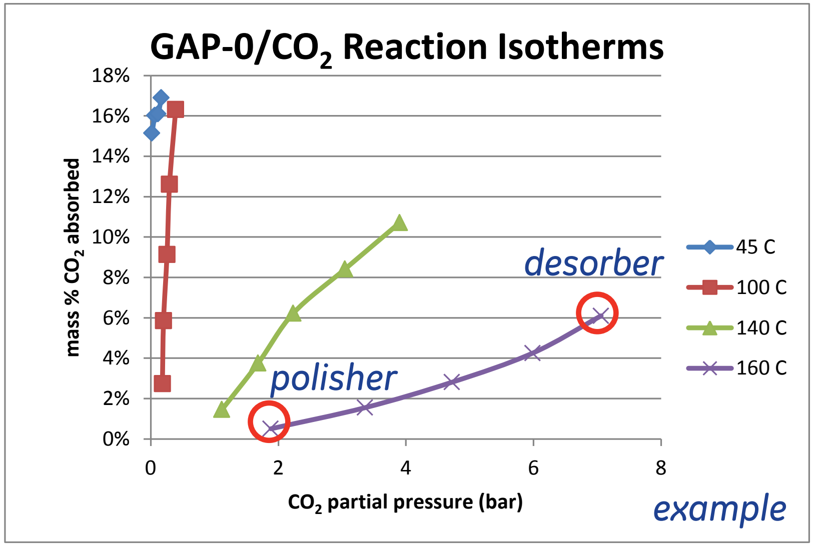


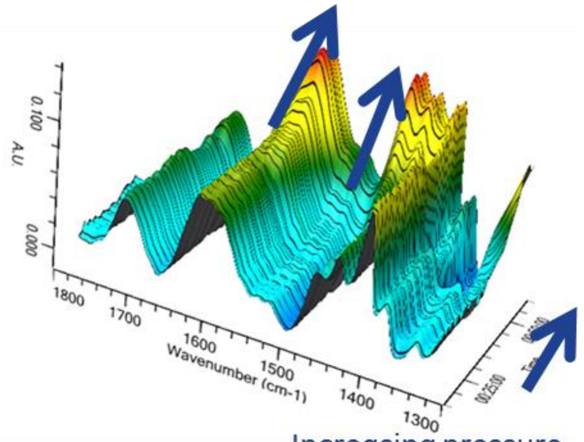
K-Tron solids feeder and 25mm extruder, connected to desorber inlet

Task 3: Design and Build – Desorber

Features

- 2-stage continuous stirred tank reactors
  - Desorber: elevated pressure – produce pressurized CO_2
  - Polisher: near-atmospheric pressure – complete solvent regeneration
- Range of residence times
  - 3.7L – 5L vessels
  - Liquid Level Control
- Controlled heating, pressure
  - Temperatures up to 180°C
  - Pressures up to 10 bar
  - Cool lean liquid before return to storage
- Measure liquid composition with inline IR probe





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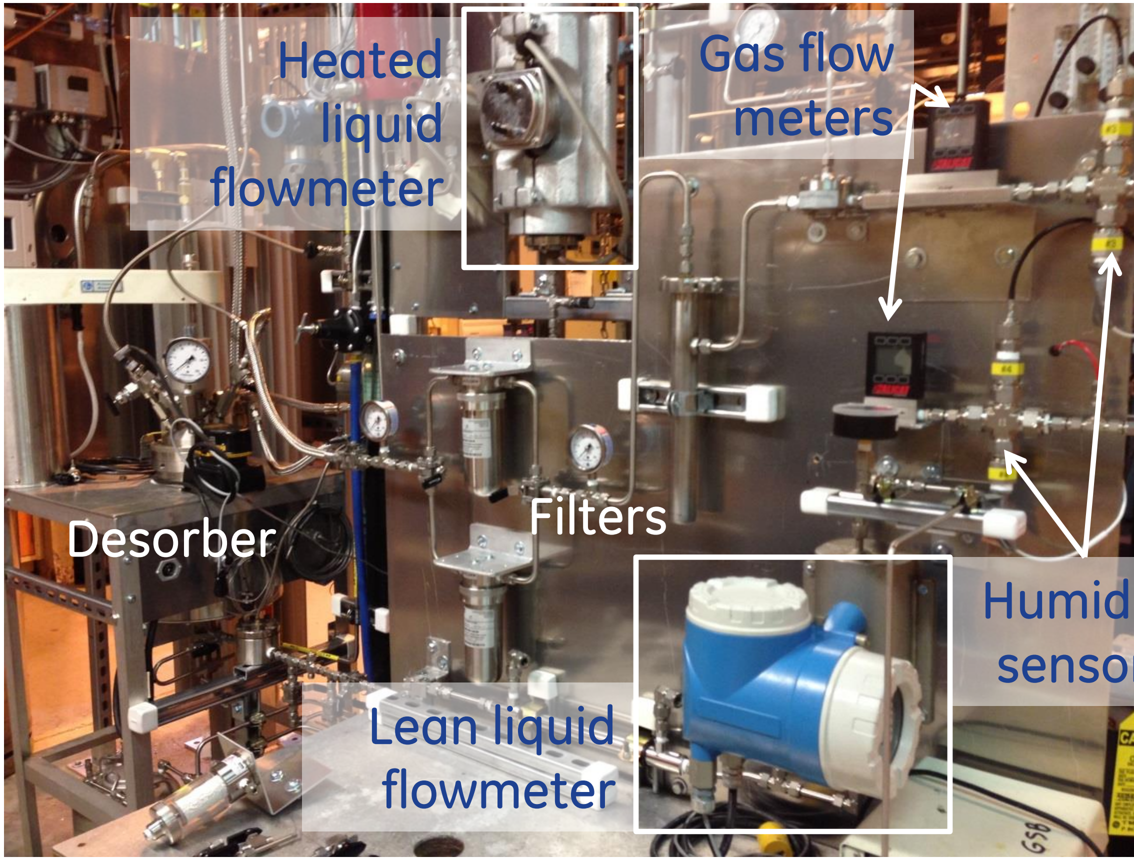
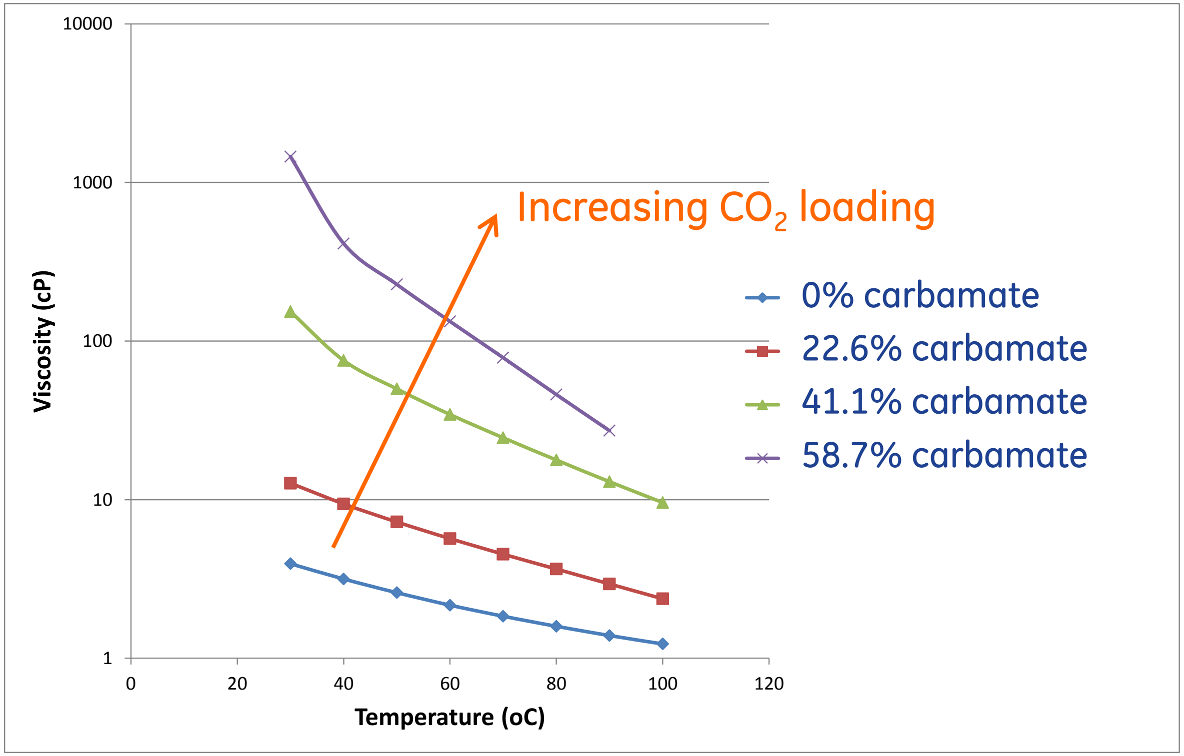
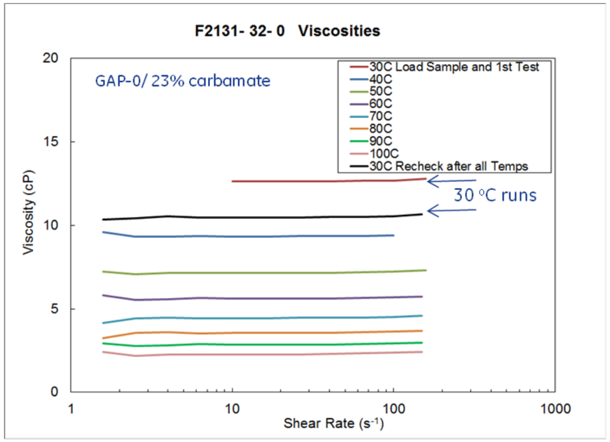
Task 3: Design and Build – Desorber



Pressurized and atmospheric pressure desorbers

Task 3: Design and Build – Desorber





- Measured viscosity of <u>homogenous</u> GAP-0 / GAP-0 carbamate mixtures
- Newtonian flow characteristics (shear-independent)
- Important data for rigorous modeling and pump selection at scale

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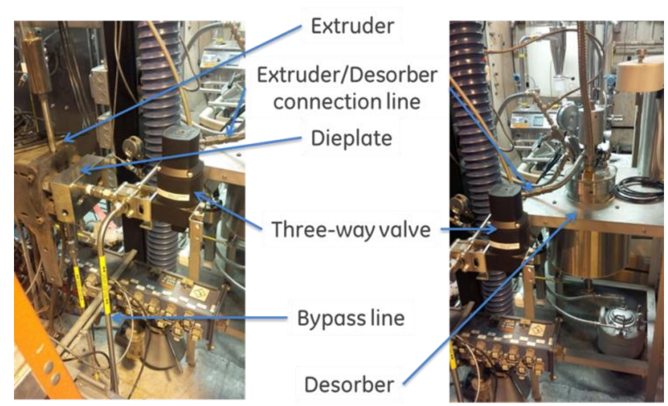
2/23/2015

Task 3: Design and Build – Integrated System

Features

- Controls and instrumentation
  - Gas flow controllers and meters
  - Liquid flow controllers and meters
  - Gas composition by Mass Spec, Humidity sensors
  - Liquid composition by IR
  - Temperature controllers and indicators
  - Pressure controllers and gauges
- Data logging
- Engineering controls (pressure relief, toxic gases)
- Unit ops integration
  - Absorber → Extruder solids transfer design in progress
  - Extruder → Desorber installation complete
  - Solvent return from Polisher → Lean Storage design complete



Task 3: Design and Build – Experiment Plan

	Absorber	Extruder	Desorber
Vary	• Gas inlet composition • Gas flow rate • Liquid flow rate • Gas inlet T • CO_2 : GAP-0 mole ratio • Atomizer type & settings	• Solids flow rate • Screw RPM • Screw design • Barrel T profile • Outlet pressure	• Feed rate • Temperature • Pressure • Agitation rate • Residence time
Measure	• % CO_2 capture • % GAP-0 conversion • Gas outlet T • Solids yield	• Maximum delivery pressure	• % GAP-0 conversion • CO_2 flow rate
Optimize	High % GAP-0 conversion (high quality solids)	High delivery pressure (stable solids seal)	• High CO_2 desorbed at pressure • Complete solvent regeneration for recycle

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BP1 Milestones and Success Criteria

Budget Period	Task	Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments
1	1	Updated Project Management Plan	1/31/2014	1/31/2014	Project Management Plan file	
1	1	Kickoff Meeting	12/31/2013	11/20/2013	Presentation file	
1	2.1-2.2	Preliminary process and cost modeling complete	3/31/2015		Preliminary Process and Cost Modeling Report	on track to meet planned completion date
1	3.1	Absorber Built and Operational	12/31/2014	12/31/2014	Research Performance Progress Report file	
1	3.2	Extruder Built and Operational	3/31/2015		Research Performance Progress Report file	on track to meet planned completion date
1	3.3	Desorber Built and Operational	12/31/2014	12/31/2014	Research Performance Progress Report file	
1	3.4	Integrated system design complete	3/31/2015		Bench-Scale System Design Topical report	on track to meet planned completion date

BP1 Success Criteria

- ✓ Unit operations are built and operational
- ✓ 90% CO_2 Capture, <$50/tonne CO_2

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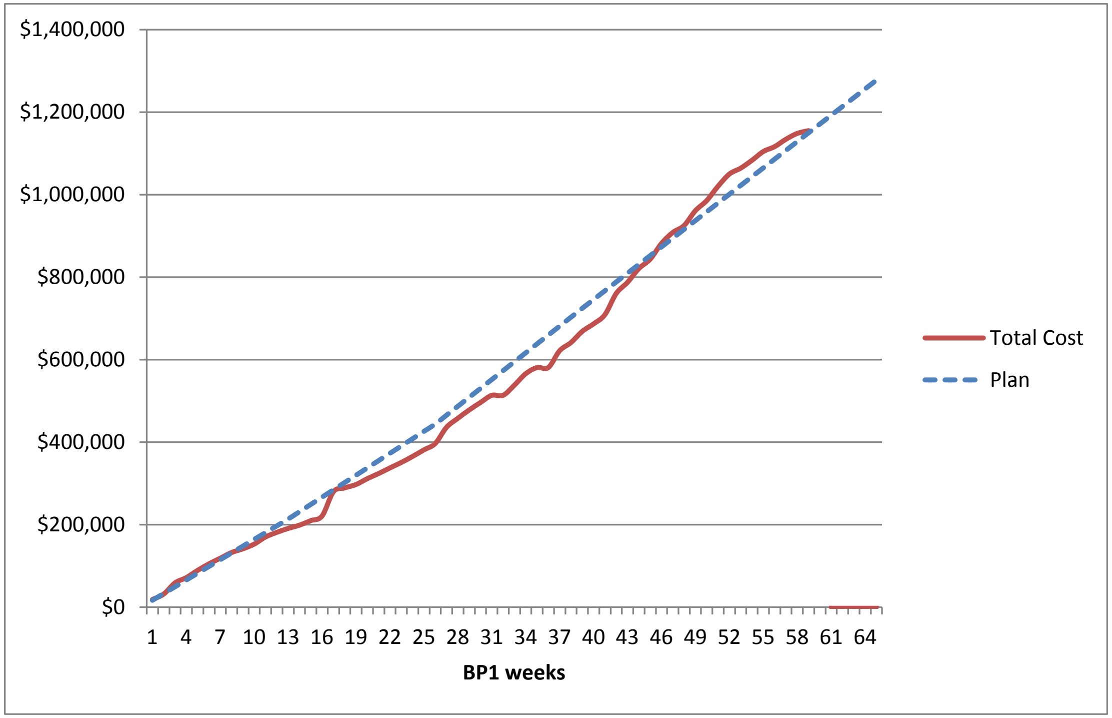
BP1 Budget Status



	BP1 (k$)
Budget	$1277
Total through Week 59	$1155
% of BP1 schedule	92%
% of BP1 cost	90%

On track to meet BP1 plan

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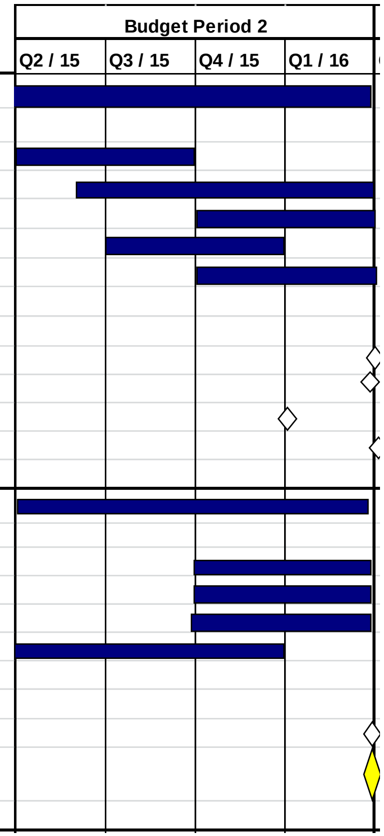
BP2 Project Schedule and Budget



Task 4 Perform bench-scale testing on unit ops

4.1 Procure solvent
4.2 Determine operating parameters for unit ops
4.3 Determine scale-up effects
4.4 Determine suitable materials of construction
4.5 Assemble components into continuous system

Milestones:
- Absorber parameters established
- Extruder parameters established
- Desorber parameters established
- Continuous system assembled

Task 5 Perform technology assessments

5.1 EH&S Risk Assessment
5.2 Update capture cost model
5.3 Update Process Model to include integrated system performance
5.4 Determine Solvent Manufacturability

Milestones:
-Technology EH&S risk assessment
- Go /no go decision based on predicted performance of 90% CO_2 capture with $45/tonne CO_2 capture cost

	BP2 (k$)
DOE Share	$652
GE Share (20%)	$163
Total	$815

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BP2 Milestones and Success Criteria

Budget Period	Task	Milestone Title/Description	Planned Completion Date	Actual Completion Date	Verification Method	Comments
2	4.2	Absorber Parameters Established	3/31/2016		Unit Operations Testing Topical report	
2	4.2	Extruder Parameters Established	3/31/2016		Unit Operations Testing Topical report	
2	4.2	Desorber Parameters Established	12/31/2015		Unit Operations Testing Topical report	
2	4.5	Continuous System Assembled	3/31/2016		Research Performance Progress Report file	
2	5.1	Technology EH&S Risk Assessment	3/31/2016		EH&S Risk Assessment Topical report	
2	5.2	Preliminary cost study completed	3/31/2016		Preliminary Cost Study report	

BP2 Success Criteria

- >90% GAP-0 conversion in absorber, reactor T < 90°C
- <5% solids lost from absorber solids collection
- >90% of carbamate conversion dictated by isotherms at T, P in pressurized desorber
- >95% of carbamate conversion in atmospheric desorber (polisher)
- 90% CO_2 Capture, <$45/tonne CO_2

Thank You

- NETL
  - David Lang
- GE GRC Project Team
  - Mike Bowman, Joel Caraher, Wei Chen, Rachel Farnum, Mark Giammattei, Terri Grocela-Rocha, Robert Perry, Gosia Rubinsztajn, Surinder Singh, Irina Spiry, Paul Wilson, Benjamin Wood
- Coperion
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